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Environmental Effects of Dredging Technical Notes



SEDIMENT RESUSPENSION BY SELECTED DREDGES

PURPOSE: The size and concentration of sediment plumes measured in field studies of selected dredging equipment are described. This information is useful when sediment resuspension must be minimized because of adverse environmental impacts which may include the release of sediment-associated chemical contaminants. The information presented here is intended to supplement and update information given in a previous technical note on the same topic (Hayes 1986a).

BACKGROUND: Dredging operations may be required to comply with in-stream State water quality standards based on maximum allowable concentrations of inorganic and organic compounds. Although the majority of materials requiring maintenance dredging in the United States is uncontaminated, the removal of contaminated sediments (estimated to be less than 10 percent of maintenance materials) poses a serious problem. Hence, a project to study the potential for contaminant release during dredging has been initiated through a field studies program. The field studies described herein were conducted by the Waterways Experiment Station under the Improvement of Operations and Maintenance Techniques (IOMT) research program and in cooperation with other US Army Engineer Districts to evaluate the sediment resuspension characteristics of selected dredges (McLellan et al., in preparation).

The release of hydrophobic (strongly adsorbed) chemicals can be evaluated by examining the transport of resuspended sediments. The release of poorly adsorbed chemicals to the water column is a more complex problem because these contaminants can disassociate from sediment particles. Evaluation of dissolved chemical release at the point of dredging may be more appropriately addressed by laboratory studies, such as elutriate testing (Environmental Effects Laboratory 1976, USEPA/USACE 1977), to evaluate contaminant release in the more biologically available, water phase. The problem of adverse environmental impacts from dredging contaminated sediments has been recognized by the Dutch and the Japanese, who have developed specially designed dredges, which are generally not readily available in the United States, for minimizing resuspension of contaminated sediments.

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Introduction

Dissolved organic and inorganic pollutants in the environment may become adsorbed to sediment particles and, through deposition, form reservoirs of pollutants in bottom sediments. Many pollutants, such as hydrophobic organics (e.g. PCBs) and some inorganics, have a tendency to remain strongly adsorbed to sediments even after mechanical resuspension into the water column as a result of dredging activities. Hence, the resuspension and dispersion of sediment during dredging operations was measured to determine the potential for release of strongly adsorbed chemicals into the water column. Three conventional dredges were examined: hydraulic pipeline cutterhead dredges; hopper/dragarm dredges; and mechanical (clamshell/bucket) dredges. Methods for controlling sediment resuspension from these dredges have been described in other publications (Raymond 1984; Hayes, Raymond and McLellan 1984; Hayes 1986a). These control methods include modification of equipment operation and equipment design.

Scope

Potential sources of sediment resuspension considered here are those directly associated with dredging and material handling equipment. (Sediment resuspension by support craft and from the material disposal operation are not considered in this analysis.) This note considers some methods for control of the dredging operation without major equipment modification to minimize sediment resuspension at the point of dredging. The vertical and horizontal distribution of resuspended sediment from conventional dredges was evaluated by measuring the total suspended solids (TSS) concentration (inclusive of background suspended sediment) at locations throughout the water column. These data are graphically presented in figures later in this note to compare plume size and TSS concentrations between different dredges.

Sampling and Data Analysis

Water column sampling was performed by taking grab water samples throughout the resuspended sediment plume. The TSS levels were averaged over the duration of the dredging project and are presented for 25-, 50-, 75-, and

100-percent sections of the water column depth. Isopleths showing lines of constant TSS concentration were drawn, using an interpolation algorithm to depict plume dimensions in horizontal or vertical sections of the water column.

Results

Cutterhead dredge

The cutterhead dredge is a hydraulic suction pipeline with a rotating cutterhead attached to the suction intake to mechanically assist in the excavation of consolidated material. Mechanical mixing by the rotating cutterhead is a major factor in sediment resuspension by this type of dredge. Cutterhead blades are designed to direct loosened material efficiently toward the suction intake. Efficient operation of a cutterhead dredge and minimization of sediment resuspension can be achieved by proper dredge design and operation. The intake velocity of the suction mouth must be sufficient to remove all of the material excavated by the cutterhead blades, or the excess material will enter the water column. The depth of cut should approximate the diameter of the cutterhead, as overburial of the dredge head tends to result in excessive sediment resuspension. High swing speeds and cutter rotation speeds may also result in excessive sediment resuspension at the point of dredging (Hayes 1986b; Hayes, McLellan, and Truitt, in preparation). Sediment resuspension from cutterhead dredges is chiefly in the lower portion of the water column. Figure 1 shows plume TSS concentrations measured at the Calumet Harbor project. Plume TSS concentrations at 100-percent depth are twice as high as those measured in the upper 25 percent of the water column.

Hopper/dragarm dredge

Hopper/dragarm dredges are seagoing vessels that trail a hydraulic suction line and draghead for removal of bottom sediments. Materials are excavated and pumped through the dragarm into hoppers located in the vessel hull. Hoppers are sometimes allowed to overflow supernatant until the contents are of a high enough density to achieve an "economic load." Hopper overflow may be quite turbid when dredging fine-grained materials that do not settle rapidly in the hopper bins. Aside from possibly requiring rehandling if currents do not move sediments away from the dredging site, overflow of fine materials into the top portion of the water column is highly visible and

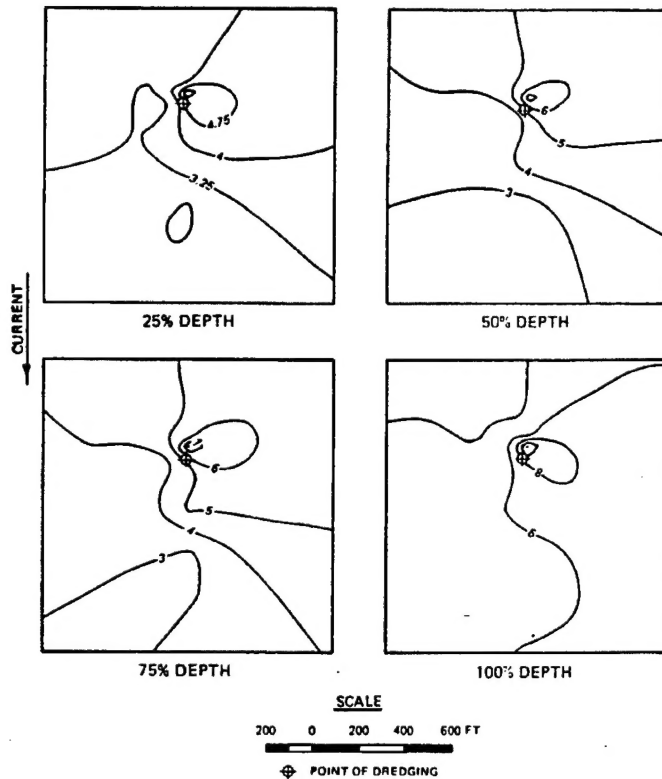


Figure 1. Plan view of resuspended sediment plume caused by a cutterhead dredge at Calumet Harbor; sediment concentration isopleths (milligrams/litre) are shown for 25-, 50-, 75-, and 100-percent depths of the water column. Background TSS concentrations ranged from 2 to 5 mg/l

aesthetically displeasing. If sediments are contaminated, pollution of the water column may be a problem. Figure 2 shows a sediment plume caused by a hopper/dragarm dredge (with overflow) at Grays Harbor, Washington. Sample boats anchored behind the passing hopper/dragarm dredge measured the decay of the sediment plume as a function of time or distance behind the dredge. During dredging with overflow, high TSS concentrations are shown near the top of the column and TSS levels of around 700 mg/l developed near the bottom as the plume settles. Figure 3 shows the resuspended plume caused by the hopper/dragarm dredge without overflow. Plume TSS concentrations are negligible in the upper water column and only 40 to 50 mg/l near the bottom.

Clamshell dredge

A clamshell dredge is a mechanical device operated by a crane and is

Figure 2. TSS concentration isopleths (milligrams/litre) in a vertical section of the water column directly behind a hopper dredge during overflow operations at Grays Harbor, Washington. Background TSS concentrations ranged from 28 to 60 mg/l

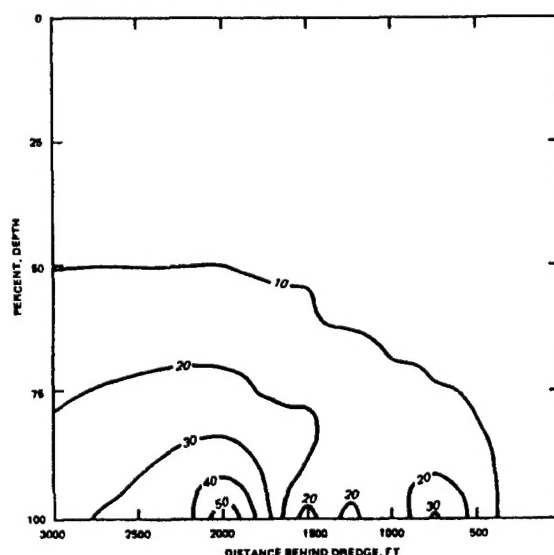
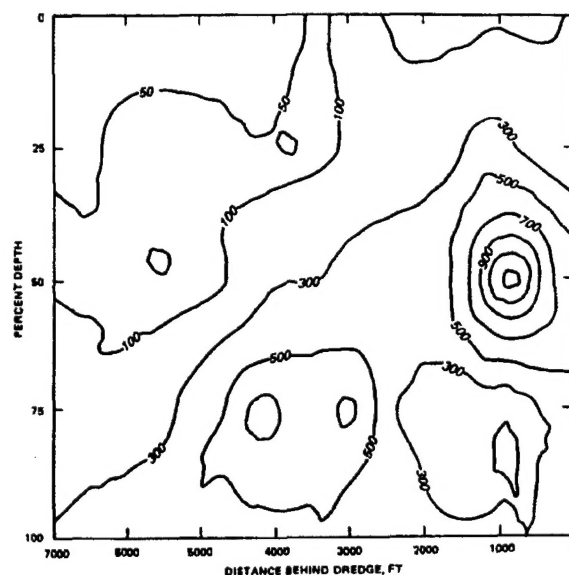


Figure 3. TSS concentration isopleths (milligrams/litre) in a vertical section of the water column directly behind a hopper dredge during nonoverflow operations at Grays Harbor, Washington. Background TSS concentrations ranged from 12 to 54 mg/l

capable of excavating material at near in situ density. Sediment resuspension from clamshell dredges can be controlled, sometimes at the expense of dredge production, through careful operation, such as reducing the speed at which the

crane lowers an empty bucket through the water column to pick up a load of sediment, and the rate at which the full bucket is lifted through the water column to remove the excavated material. Limiting the practice of smoothing the excavated area by dragging the bucket along the bottom may also reduce sediment resuspension at the point of dredging. Figure 4 shows a sediment plume caused by a clamshell dredging operation at the Calumet River project. TSS concentrations of 140 mg/l are shown at 100-percent depth due to mixing caused by bucket impact and withdrawal from the bottom. High TSS levels are evident throughout the water column due to erosion and leakage of material from the bucket as it is lifted to the surface. Enclosed clamshell buckets have been designed to reduce erosion and leakage of material into the water column, but they have not been extensively tested.

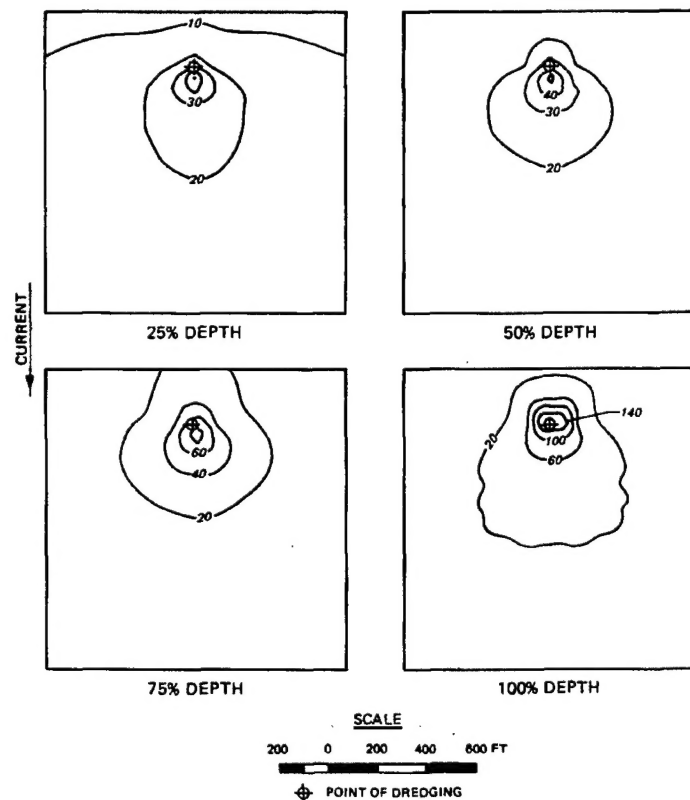


Figure 4. Plan views of resuspended sediment plume caused by a clamshell operation at Calumet River; sediment concentration isopleths (milligrams/litre) are shown for 25, 50, 75, and 100 percent of the water column depth. Background TSS concentrations ranged from 10 to 12 mg/l

Plume comparisons

Results show that the TSS levels from clamshell dredging (Figure 4) are an order of magnitude higher than from cutterhead dredging of similar sediments at the Calumet project (Figure 1). Also, clamshell dredging distributed sediment throughout the water column, whereas the plume from cutterhead dredging remained in the lower part of the water column. It is clear that hopper overflow causes high levels of TSS throughout the water column (Figure 2) and that concentrations are more than an order of magnitude higher than for hopper/dragarm dredging without overflow (Figure 3). Figure 5 is a summary of the worst-case sediment resuspension results from the conventional dredges studied under the IOMT program (McLellan et al., in preparation).

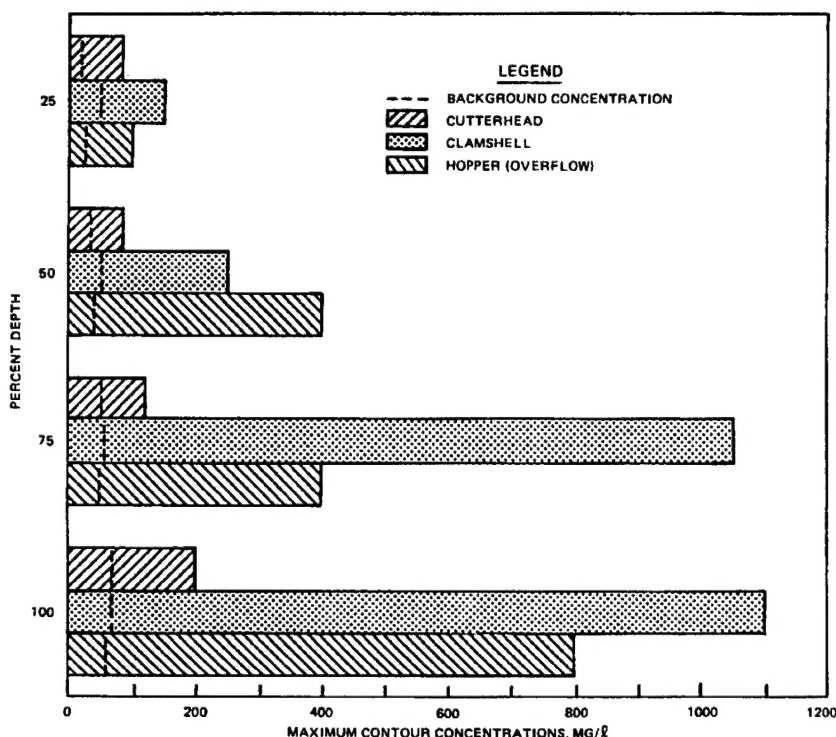


Figure 5. Maximum TSS concentration levels (milligrams/litre) measured for cutterhead, clamshell, and hopper dredges during IOMT field studies

Some dredging operations studied under the IOMT program were not strictly controlled to minimize sediment resuspension, but all sediments were maintenance materials and are therefore similar in that they are unconsolidated and composed of relatively fine particles. Nevertheless, the field study results

were consistent in showing the cutterhead dredge to cause significantly lower TSS concentrations than the hopper/dragarm dredge, with overflow, followed by the clamshell dredge.

Conclusions

The size and concentration of sediment plumes show the potential for the release of strongly adsorbed pollutants into the water column by particular dredges. Figure 5 is useful for evaluating dredge types in applications where materials are contaminated, or when sediment resuspension may have a negative impact on the environment. The cutterhead dredge is a logical selection for controlling sediment resuspension while maintaining efficient production. In applications where a cutterhead dredge is not practical (i.e., for work in open seas with significant wave heights (over 3 ft), when a hopper/dragarm dredge would be preferred, or around docks and other harbor installations where a clamshell dredge would be preferred), sediment resuspension from clamshell and hopper dredges can be controlled through control of the dredging operation. Accordingly, limiting overflow from hopper/dragarm dredging (Figure 2) showed significant benefits by reducing water column TSS levels to near background levels compared to the water quality conditions during hopper overflow (Figure 2).

Future Directions

Plume sizes and concentrations are useful in estimating the relative merits of different dredge types for the control of sediment resuspension. Future research efforts in this area will be to collect data for estimating the mass rate of sediment resuspension (kilograms/second or kilograms/cubic metre) for a particular dredge type under a given set of project conditions. This information is useful as input for and in development of predictive models for evaluating the potential environmental impact of sediment resuspension and contaminant release during dredging. Modifications of the laboratory elutriate test will be investigated as a tool for use in conjunction with sediment resuspension models to estimate the release and distribution of the more biologically available, soluble pollutants.

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